Cardiac electrophysiologists’ use of the coronary sinus (CS) to map and ablate accessory pathways and implant left ventricular leads has emphasized the need for understanding CS anatomy. In this review, we briefly examine the developmental and radiological anatomy of the CS and discuss in detail the gross anatomy of this cardiac vein. We highlight the correlations of the acquired anatomical knowledge relevant to clinical electrophysiology practice.

Keywords  
Coronary sinus • Cardiac veins

Introduction

The coronary sinus (CS) has become a clinically important structure especially through its role in providing access for different cardiac procedures. Historically, cardiac vascular studies have focused mainly on the coronary artery circulation. Although not studied to the extent of the coronary arteries, the coronary venous system is important in many electrophysiological procedures, including arrhythmia ablation, biventricular pacing, and for deployment of an array of cardiac devices.1–3 The advent of advanced invasive and interventional cardiac treatment and management tools for common disorders like heart failure has made understanding of CS anatomy necessary.4–6 There is also an increased interest in the CS as an access point for interventionalists for ablation procedures of an arrhythmia source and for mapping.7–9 The CS is the main cardiac vein. This review will describe the basic gross and developmental anatomy of the CS and venous supply with focus on specific anatomical aspects that are encountered in invasive and interventional settings.

Coronary sinus anatomy

The myocardium drains mainly by two groups of veins: the tributaries of the greater and smaller cardiac veins, or the Thebesian veins. The main vein of the greater venous system is the CS that runs in the posterior aspect of the coronary groove. The anterior wall of the left ventricle and the interventricular septum are drained by branches of the anterior interventricular vein, known as the great cardiac vein on the annulus.3,10,11 The course of the anterior interventricular vein is similar to the adjacent left anterior descending artery in the interventricular groove. In a study using electron beam computed tomography (CT), the anterior interventricular vein was visualized in up to 100% of subjects scanned.12 In addition, the diameter of the anterior interventricular vein was seen to be similar to the neighbouring artery for the length of its course. The great cardiac vein in turn joins the main posterior lateral vein to form the CS. Other major tributaries entering the CS include inferior left ventricular vein and the middle cardiac vein (MCV) that drain the posterior aspect of the left ventricle. The atrial myocardium also drains into the CS via the various atrial veins and the vein of Marshall. The vein of Marshall is a remnant of the left superior vena cava; it runs along the posterior aspect of left atrium and is formed by the junction of the great cardiac vein and the posterolateral vein.13 The right atrium and the posterior and posterolateral portions of the right ventricle are drained by the small cardiac vein into the CS at the ostium of the right atrium.

The smaller cardiac venous system is the Thebesian venous network. This system is responsible for draining the inner layers of the myocardium of the right ventricular venous system and portions of the interventricular septum directly into the right ventricle via orifices that are often <0.5 mm in diameter.

Embryology

Development of the CS occurs through differentiation of the sinus venosus (Figure 1). During foetal development, a single heart tube separates around the third week giving rise to the primordial...
atrium and sinus venosus. Initially, the sinus venosus opens into the posterior wall of the right atrium. Around the fourth week, the sinus venosus differentiates into right horn and left horns which through a process of degeneration and absorption, give rise to the venous channels entering the right atrium. The right horn is absorbed by the right atrium and persists as the smooth portion of the superior vena cava as well as the area between the vena cava extending into the CS ostium, whereas the left horn undergoes progressive degeneration until the 10th week, giving rise to the CS.14,15

Detailed anatomy

Coronary sinus

The length of the CS varies from 3 to 5.5 cm and is dependent on the site of the drainage of the posterolateral vein.16 The diameter of the CS is also variable and is dependent on the loading conditions, presence and extent of atrial myocardium with the coronary vein, and the presence of underlying cardiac disease or prior cardiac surgery. The CS lies in the sulcus between the left atrium and ventricle and is a continuation of the great cardiac vein from the valve of the great cardiac vein to the ostium of the CS as it terminates in the right atrium. The CS begins proximally at the right atrial orifice and ends distally at the valve of Vieussen’s. The CS receives blood from the ventricular veins during ventricular systole and empties into the right atrium during atrial systole.

The wall of the CS is made up of striated myocardium that is continuous with the atria, forming a myocardial sleeve around the venous system17 (Figure 2). This sleeve does not usually extend into the ventricle myocardium. In variations, where a continuation into the ventricle is formed, however, an atrioventricular bypass tract referred to as an epicardial pathway is formed.18

The CS, like the rest of the cardiac venous system, contains various valves.9,20 The most common valve is the Thebesian valve at the ostium of the CS. The Thebesian valve is a crescent shaped structure often found guarding the mouth of the CS as it opens to the right atrium. The Thebesian valve is highly variable and occasionally may present an obstruction during cannulation of the CS.21 The CS also contains the valve of Vieussen’s that often marks the end of the vein. These venous valves are also frequently found at the entrance of the ventricular veins into the great cardiac vein. The right ventricular venous system drains directly into the right ventricle through the Thebesian venous network.

The CS ostium is 5–15 mm in diameter and is located on the posterior interatrial septum anterior to the Eustachian ridge and valve and posterior to the tricuspid annulus.11,17 The ostium is often covered, to a variable extent, by the Thebesian valve. The valve usually covers the superior and posterior surfaces of the ostium, but may be covered completely with formation of fenestrations. In rare instances, the valve may cover the inferior hemi-circumference.

Clinical application

The CS has increasingly been recognized as a vital structure for an array of clinical interventions. The CS is of interest to the electrophysiologist because it provides a useful route for mapping and ablation of left-sided accessory pathways. Nevertheless, pathways that are located close to the mitral valve may be difficult to ablate given their significant distance from the CS. In addition, the CS is an electrophysiologically active structure. Previous studies have demonstrated the capability of spontaneous depolarization and slow conduction in the smooth muscle of the CS, providing inherent automaticity.9,22–24 Also, the atrial myocardial sleeve that covers the proximal CS provides the ability for conduction and automaticity, forming an electrical connection between the two atria. Studies have shown that this connection is of clinical importance as it may be a source of arrhythmias such as atrial fibrillation.18,23–25 Active myocardium within the CS may serve either as a source for abnormal automaticity generating a focal tachycardia or as a part of a reentrant circuit. In patients with
atrial fibrillation, although myocardial sleeves within the pulmonary veins are a more common source, CS myocardium may also initiate recurrent atrial fibrillation. Since the CS is one of the connections between the right and left atria, with Bachmann’s bundle forming the other important connection, reentrant tachycardia involving the CS muscle and both atria are sometimes seen in patients with marked atrial enlargement, especially after a surgical maze procedure.

The vein of Marshall may give rise to atrial fibrillation either by virtue of myocardial extensions into the structure or as a result of node like remnants within the vein or by virtue of the rich autonomic innervation that typically encapsulates the structure. With regard to left ventricular pacing, atrial electrograms may be sensed by the ventricular lead if it is placed too proximal (basal) within a ventricular branch of the CS.

Cannulation of the CS during interventional procedures may be complicated by obstruction due to Thebesian valves (Figures 3–5). A three-dimensional, functional anatomy study showed that Thebesian valve morphology varied greatly, and included instances of dynamic obstruction. Cannulation would be likely to be more complicated in the living heart during the cardiac cycle. Studies have demonstrated that valves that obstruct a significant portion of the CS ostium may be successfully transversed by use of modern cannulation techniques (i.e. softer-tipped sheath, pre-shaped sheath, and anterior approach).

In addition, cannulation of the CS for percutaneous mitral valve annuloplasty has been described.

Atrial venous drainage

The atrial myocardium drains into the CS via the various atrial veins and the vein of Marshall. The largest atrial vein branch usually occurs opposite to the posterolateral vein coursing between the anterior surface of the left-sided pulmonary veins and the posterior surface of the route of the left atrial appendage. This branch is an embryological remnant of the left superior vena cava. Thus, when it is completely patent, it is known as a persistent left superior vena cava. The branch is known as the vein of Marshall when it is patent in its atrial course. Occasionally, it may be partially or completely occluded; in which case it is known as the oblique vein of Marshall.

Clinical application

The left atrial veins can be used for atrial pacing. When thresholds are poor in the right atrium or precise left atrial-left ventricular synchrony is needed. Specific cannulation of the CS and then placing the lead into an atrial branch can be done. Bi-atrial pacing with both a right and left atrial lead has been attempted for pacing related therapy of atrial fibrillation.
Ventricular veins

Anterior interventricular vein

The anterior interventricular vein, the largest and most consistent of the cardiac veins, courses in the interventricular groove adjacent to the left anterior descending artery as it runs towards the base of the heart. It is the most anterior vein seen in the right anterior oblique (RAO) projection. Although the anterior interventricular vein is the venous parallel of the left anterior descending artery, its proximal tributary courses along the first diagonal branch. As it approaches the base of the heart, the anterior interventricular vein courses laterally towards the atrioventricular groove to form the great vein. A large tributary that arises proximally drains a significant portion of the anterolateral wall of the left ventricle. This apical branch is thought to be continuous with branches of the posterior and posterolateral cardiac veins in ~30% of hearts. The phrenic nerve forms an anterior relation to the anterolateral branch of the anterior interventricular vein in a fraction of patients.

Lateral cardiac veins

The lateral wall of the left ventricle is typically drained by three distinct veins (Figure 6), largest and most consistent of which is the posterolateral vein. Other veins, specifically the straight lateral vein and the anterior lateral veins are also found in this region. The posterolateral vein occurs directly opposite the vein of Marshall.

In addition to receiving tributaries from the anterior interventricular vein, the great cardiac vein also receives tributaries from left posterior vein and the left marginal vein. The phrenic nerve typically crosses superficial to the great cardiac vein and forms variable relations with the lateral vein, posterior branches of the anterolateral vein, and anterior branches of posterolateral cardiac vein. Because of the thickness of the ventricular myocardium at this site, secondary tributaries of these lateral veins often run an intramyocardial course.

Middle cardiac vein

The largest proximal tributary of the CS is the MCV (Figure 7), also known as the posterior interventricular vein. The MCV receives communications from the anterior veins as well as from branches from the septal wall and inferior walls of both ventricles. The MCV courses with the posterior descending artery in the posterior interventricular groove and enters the CS close to the right atrial orifice or, rarely, enters directly into the right atrium apical to the septal attachment of the tricuspid valve. Cardiac autonomic fibres are often found in the posterior crux near the junction of the MCV with the CS. The MCV also has a varied number of branches, the most relevant being the left marginal and inferior veins.

Posterior ventricular vein

The origin of the posterior ventricular vein is highly variable, but in ~25% of patients, the posterior ventricular vein shares a common cloacal ostium with the MCV. In some cases it has been shown to arise as a tributary from the MCV. This vein courses along the lateral wall together with the posterolateral branches of the right coronary artery and drain the lateral and diaphragmatic walls of the left ventricle. Because of its course, it may be confused with a branch of the MCV. Its distal branches often interdigitate with branches of the lateral venous system and may be closely related to the phrenic nerve.

Clinical application

The MCV can be specifically targeted for placing a left ventricular lead (Table 1). Although the MCV lies in the posterior interventricular septum various branches/tributaries drain the lateral wall.
toward this vein. Because of the unique anatomy of this vein (being perpendicular to the main access of the CS) cannulation is not straightforward. The operator typically uses counterclockwise torque to cannulate the CS. Once the CS has been cannulated, clockwise torque needs to be applied to turn the sheath or guiding catheter towards a ventricular vein. Often the posterior vein will be cannulated in this rotation and can be used. If, however, because of phrenic nerve stimulation or absence of good pacing thresholds within the vein, the guiding sheath or catheter can be withdrawn from this vein whereas continuing to apply clockwise torque. The MCV can then be cannulated just before the sheath or catheter slips out of the CS. Once entered the pacing lead can then be placed in this vein and carefully manoeuvred to the left ventricular free wall.12,14,16

The venous drainage of the lateral wall of the ventricle is variable and typically gives multiple options for the implanter.33,34

Because of the posterior and posterior lateral veins can form various angles with the main body of the CS inexperienced operators may not realize that this vein has been cannulated and unnecessarily withdraw the catheter or guiding sheath. When doubt exists as a result of prior knowledge of the anatomy of this region venography or ultrasound imaging is required. Sometimes a common ostium for the posterior and MCV occurs and may need specific cannulation either for placement of pacing leads or ablation of posterior epicardial accessory pathways.

### Thebesian venous system

The smaller cardiac venous system that is composed of small venous branches and drains the subendocardium is known as the Thebesian venous system. The Thebesian veins are vessels composed primarily of endothelial cells, which are continuous with the lining of the cardiac chambers.33 These vessels are found throughout all four chambers of the heart, but are more prominent on the right. In addition, this venous system provides drainage to the right appendage as well as a significant portion of the muscular ventricular septum.

### Radiology

With standard fluoroscopy the CS cannot be directly visualized. However, the epicardial fat found in the posteroseptal space just posterior to the CS ostium can be detected on cine fluoroscopy (Figure 8). A characteristic radiolucency best seen in the RAO projection can be noted, where the cardiac and any diaphragmatic silhouettes meet.

### Table I Clinical correlates of specific coronary venous anatomic characteristics

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<th>Coronary vein anatomy</th>
<th>Clinical application</th>
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| Coronary sinus        | Cannulation may be hindered by a large Thebesian valve  
                        | Myocardial extensions may constitute an accessory pathway  
                        | The vein is one of the primary electrical connections between the right and left atrium |
| The vein of Marshall and other atrial veins | The vein of Marshall may require ablation for atrial fibrillation |
|                       | autonomic nerves  
                        | myocardial extensions  
                        | nodal remnants |
|                       | Atrial veins can be used for pacing the left atrium |
| The anterior interventricular vein | Lateral tributaries can be used to pace the left ventricular free wall |
|                       | Ablation within this vein sometimes required for outflow tract ventricular tachycardia |
|                       | The phrenic nerve may lie close to lateral branches of this vein |
| Posterolateral vein | Ideal vein to attempt cannulation as it drains the free wall of the left ventricle |
|                       | The valve of Vieussen typically found at the ostium of this vein and can hinder cannulation |
| Posterior ventricular vein | Sometimes mistaken for the middle cardiac vein |
|                       | Lateral tributaries can be used for effective left ventricular pacing |
|                       | Cannulation of this vein at times not immediately recognized during a procedure |
| Middle cardiac vein | An option to consider for placing left ventricular pacing leads, particularly into one of the its lateral tributaries |
|                       | Well established site for posterior epicardial pathways |
|                       | Diverticula or aneurismal dilation of this vein may occur with or without associated arrhythmias |
Perhaps more importantly accurate radiographic anatomy is needed with standardized fluoroscopic views [right and left anterior oblique (LAO) projections] to guide placement of leads and sheath of catheter cannulation of the main body of this vein. In the LAO projection, when cannulating the CS, the lead catheter will be seen to move leftward after entry.14,33,34 In the RAO projection, catheter or lead movement towards the sternum (anterior) signifies cannulation of ventricular vein where as posterior deflection or orientation suggests that an atrial vein has been entered.

Multi-slice CT is used increasingly as a non-invasive alternative for preoperative evaluation of the coronary arteries and cardiac veins (Figure 9). On CT scans, the CS appears to average 30 mm in length (21–40 mm) with an average diameter of 9 mm (4–14 mm).12 The CS is clearly visible with contrast material and is identified by its characteristic vertical segment superiorly that then forms a bend or a ‘turn’ to join a horizontal segment inferiorly. The horizontal segment corresponds with the right atrial termination of the CS whereas the vertical segment, due to its oblique orientation to the CT cross-sectional slice, may be observed as a round density on some scans. The bend or ‘turn’ of the sinus, due to its oblique orientation, is seen as an oval density.36

**Summary**

Accurate knowledge of the coronary venous anatomy is essential for electrophysiologists performing left ventricular pacing procedures or radiofrequency ablation. Although many variations occur constant features include a large anterior interventricular vein that continues in the left atrial ventricular groove as the Great Cardiac vein and then joined by one or more posterolateral ventricular veins the CS forms the continuation until it drains into the right atrium. The middle cardiac and posterior veins, as well as various atrial veins including the vein of Marshall are other consistent tributaries. In this review, we discuss the gross, developmental radiographic anatomy of the important cardiac venous system to improve understanding amongst interventional electrophysiologists.

**Conflict of interest:** none declared.

**References**


